DEVELOPMENT OF EMERGING TELEMEDICINE TECHNOLOGIES WITHIN THE DEPARTMENT OF DEFENSE: A CASE STUDY OF OPERATION JOINT ENDEAVOR IN BOSNIA

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For the past several years the United States Department of Defense has been using rapid prototyping as well as integrated product and process management to enhance military health care delivery using new telemedicine technologies. This paper outlines how these concepts are being used within the DoD Telemedicine Testbed to conduct proof-of-principle demonstrations and operational testing of emerging telemedicine technologies within real-world military operational environments. The authors consider these rapid prototyping and "rapid integration" efforts to be advanced development phases of the Army's formal telemedicine acquisition program known as Medical Communications for Combat Casualty Care and DoD's Theater Medical Information Program. They examine a case study of a real-time application of rapid prototyping in a contemporary operation—Primetime III, the telemedicine augmentation of medical units supporting Operation Joint Endeavor in Bosnia. The lessons learned from this experience are important to the eventual achievement of the strategic objectives of DoD telemedicine.

During the past two years the Secretary of Defense has articulated a strategy for a new system for Department of Defense (DoD) research, development and acquisition that shifts from traditional product-based research and development to a dynamic new framework characterized by rapid prototyping, concurrent as opposed to sequential engineering, reliance on commercial-off-the-shelf (COTS) technologies, horizontally and vertically integrated teamwork, and experimentation as the heart of integrated product and process management (DoD, 1996).

The DoD Telemedicine Test Bed has adopted these principles in its own integrated framework for telemedicine research, development, and acquisition. In this system the Defense Advanced Research Projects Agency (DARPA) in partnership with the Medical Research and Materiel Command (MRMC) performs basic research and develops new technologies, such as telerobotic surgery, the personnel status physiological monitor, trauma and clinical care decision support systems, surgical simulators, and advanced diagnostic imaging systems. At its Prototype and Implementation Test Lab (PITLAB), the Army Medical Research and Materiel Command's Medical Advanced Technology Management Office (MATMO) integrates new technology developed by DARPA and COTS technologies into prototype systems tailored to satisfy military requirements as articulated by the Army, Navy, and Air Force user communities (Figure 1).

Prototypes are then evaluated by users in a variety of settings. These settings range from Advanced Warfighting Experiments (AWEs) staged at U.S. Army Battle Labs, or joint service exercises in which the Army, Navy and Air Force use test environments appropriate to their unique missions. Another option for blended telecommunications and advanced medical diagnostic technologies is the Center for Total Access, a joint initiative between the U.S. Army Signal Center and the Dwight David Eisenhower Army Medical Center at Fort Gordon, Georgia. Large field medical units at Fort Hood, Texas, and Fort Bragg, North Carolina, also offer excellent test beds for user experimentation and feedback.

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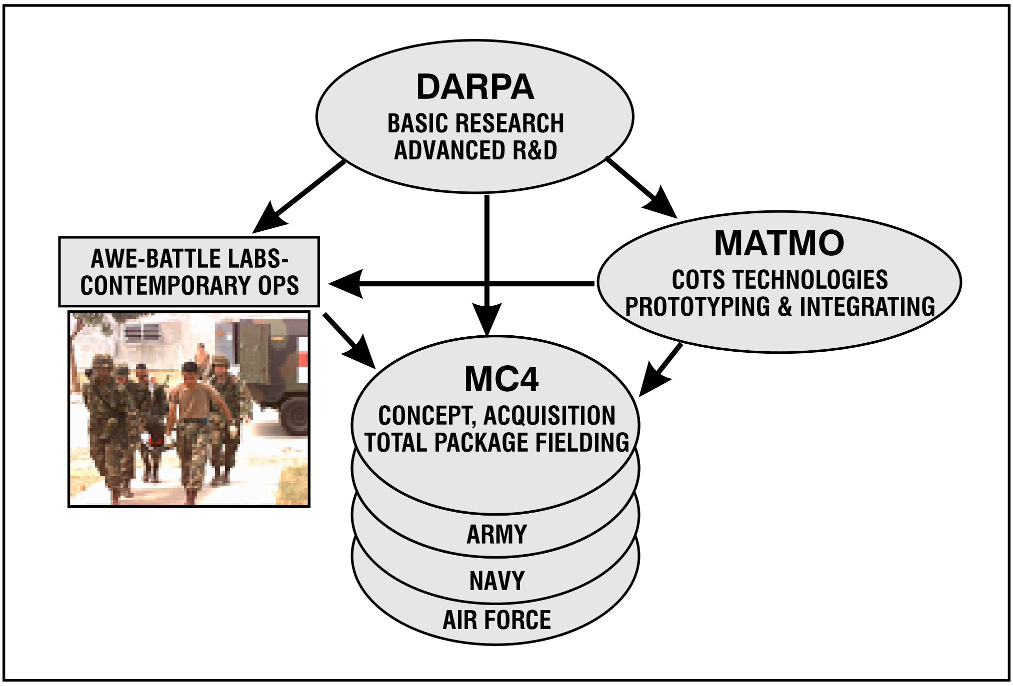

Figure 1. Department of Defense Telemedicine, Research, Development, and Acquisition

In addition, tertiary care regional military medical centers such as the Walter Reed Army Medical Center and Bethesda Naval Medical Center, both in Washington, D.C., Wilford Hall Air Force Medical Center in Texas, Tripler Army Medical Center in Hawaii, and Madigan Army Medical Center in the state of Washington have been active test sites for both peacetime and combat support telemedicine evaluation programs (Crowther and Poroputich, 1995; Lyche et al., 1995; Delaplain, Linborg, Norton, and Hastings, 1993). Contemporary operations such as the U.S. Armed Forces commitments to Somalia, Haiti, the Middle East, or Operation Joint Endeavor in Bosnia have offered a rich environment for rapid prototyping of integrated technology testing (Cawthon et al., 1991; Detreville et al., 1995; Gomez, 1994; Crowther and Poropatich, 1995), because they constitute a full range of health care services with networked telecommunications and information technology implementations ranging from far forward combat casualty care applications to subspecialty teleconsultation at the tertiary care medical centers. The DoD Telemedicine Testbed at Fort Detrick (MATMO) also leverages telemedicine experience and work done outside the DoD (Sanders and Bashshur, 1995; Galvin et al., 1995; Goldberg et al., 1994; Perednia and Allen, 1995; Mun, Alsayed, Tohme, and Wu, 1995)..

Within this rapid prototyping model, validated technologies destined for combat casualty care support are transitioned to a Program Manager (PM). The Army has recently established a PM for Medical Communications for Combat Casualty Care (MC4). The PM is responsible for acquisition of a completed technology system. He ensures that effective "process management" strategies are in place and that appropriate organizational, concept, doctrine, and training issues have been addressed prior to large-scale acquisition and fielding to operational forces.

The introduction of robust telecommunications, information technology and advanced diagnostic capabilities into health care has profound effects on established work patterns and responsibilities. Successful technology integration projects require comprehensive user requirements, organizational work process, and training analysis prior to large-scale acquisition and total package fielding (Appleton, 1993). The PM works closely with the user communities to ensure that important organizational assumptions and strategies regarding human–computer interfaces, work pattern changes, and personnel management are tested before there is widespread fielding.

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The DoD can take advantage of a wide range of assets to further develop telemedicine. These assets are coupled with the DoD's relative immunity from a number of complex private sector impediments to telemedicine development. These impediments include restricted interstate medical licensing, lack of fee-for-service reimbursement, and unclear liability relationships (Perednia and Allen, 1993). These circumstances place DoD in a unique position to explore, evaluate, and continuously improve telemedicine technologies across a broad spectrum of clinical applications and user settings. This exploration could benefit both soldiers and civilians.

MEDICAL COMMUNICATIONS FOR COMBAT CASUALTY CARE (MC4)

The U.S. Army formally articulates its program for telemedicine support of ground forces as having five strategic thrusts. Far forward applications will provide front-line medics and small forward medical support units with still imagery, interactive videoteleconferencing (VTC), and diagnostic scopes. Eventually, far forward medics will have access to technology that can monitor the physiological status of individual soldiers and provide real time medical situational awareness of where and how medical assets are being used on the battlefield.

The Digital Field Medical Treatment Facility will provide ground support forces with telemedicine-augmented deployable hospitals. These hospitals will include capabilities for computed radiography, computed tomography, teleradiology transmission, VTC and diagnostic scopes, high-resolution still imagery, teledentistry, computerized hospital and patient information systems, Internet access, and enhanced wireless, hospital, and patient information management systems.

The Expert Tertiary Care Host provides forward deployed forces with access to specialty and subspecialty teleconsultation from medical centers located in the continental United States. These requirements include the development of technology for regional medical centers to send and receive transmissions from remotely located forward deployed medical units, and to distribute VTC, image acquisition, and electronic patient information throughout the hospital. Telemedicine capabilities within medical centers will be based on the concept of clinical workstations that provide the clinician with an integrated telepresence that includes real time VTC, ubiquitous access to digital medical imaging, and patient information.

Telemedicine Sustainment ensures that a strategic telecommunications infrastructure is available to support telemedicine requirements from the continental United States to forward deployed locations around the world. The telemedicine sustainment thrust includes ensuring the availability of high-bandwidth satellite and terrestrial communications to deployed medical forces and research into the enhanced utilization of frame relay and asynchronous transfer mode (ATM) technologies to support multimedia, simultaneous medical transmissions of voice, text, and video. Another important area of concern is the development of enhanced medical compression algorithms that will allow the transmission of medically relevant information at lower bandwidths.

The last area, Emerging Technologies, supports the integration of what is now basic research into prototyping, advanced development, and eventually, fielding to operational forces. These technologies include the further development of advanced surgical simulators to enhance surgical training and planning; the integration of the personnel status physiological monitor into the broader U.S. Army Warrior Status monitor program; and the testing, evaluation, and fielding of the Life Support for Trauma and Transport (LSTAT) system, a self-contained critical care transport module with noninvasive, miniaturized diagnostic modalities, resuscitation, information management, and communications capabilities. The continued research into surgical robotics and expert decision support systems is another area of research interest that DARPA has funded for development.

Theater Medical Information Program (TMIP)

The Theater Medical Information Program (TMIP) is DoD's programmatic effort to fully integrate telemedicine and medical informatics systems support for deployed forces from all services. The concept is to provide a seamless continuum of information-based health care services from the most forward deployed forces around the world to the sustaining base DoD and Veteran's Affairs medical centers in the United States. To accomplish this, the TMIP will integrate and extend support to deployed forces for DoD's functional medical information systems such as the Composite Health Care System (CHCS) (originally designed as a peace-time inpatient and outpatient hospital information system), the Defense Blood Standard System (DBSS), the Transportation Command Regulating and Command & Control Evacuation System (TRAC2ES) and the Theater Army Medical Management Information System (TAMMIS). The Army's MC4 program is an integral part of the TMIP effort.

Context For Primetime III - Telemedicine Augmentation to Bosnia

When President Bill Clinton directed the deployment of U.S. Armed Forces in support of the Dayton Peace Accords in mid-December of 1995, one of the primary concerns of U.S. policy makers was the possibility of incurring casualties among U.S. ground forces. This concern was credible in the aftermath of U.S. casualties in Somalia, of the shooting down of a U.S. aircraft in the months prior to the Dayton Peace Accords, and numerous hostage takings (and releases) of United Nations soldiers earlier in 1995.

Various combinations of telemedicine technologies have been tested in joint service exercises, U.S. Army AWEs, on board deployed naval vessels, and within the peacetime Military Health Service System (MHSS). The U.S. military has also executed real world missions with these technologies in a wide variety of contingency operations over the previous five years.

Deployments in which telemedicine has been used to provide real world medical support include Saudi Arabia, Kuwait, Somalia, Haiti, Cuba, Panama, Croatia, and Macedonia. By the time of the Dayton Peace Accords, continued improvements in commercially available information technologies such as computer networking, data compression, and high-bandwidth telecommunications, linked with improved medical imaging and diagnostics technologies, offered military medical planners with an unprecedented opportunity to deploy integrated telemedicine capabilities far forward into a military theater of operations.

Consequently, the senior civilian and military leadership of the Military Health Service System decided in late December of 1995 to use a wide variety of telemedicine technologies to augment the U.S. medical units assigned to Task Force Eagle, the U.S. component of Operation Joint Endeavor in Bosnia and Hungary, as supported from the Landstuhl Regional Medical Center in Germany. The technical support task force formed to implement this intent is called Primetime III. The Commander of U.S. Army Medical Research and Materiel Command was delegated direct responsibility for the day-to-day supervision and execution of the mission.

Primetime III

Primetime III is a real-world rapid prototyping proof of principle demonstration for the MC4 and TMIP programs described above; this is a “first-shot” effort at deploying an integrated theater medical information solution tailored to the specific missions of Task Force Eagle and Operation Joint Endeavor.

The telemedicine solutions deployed are intended to allow medical commanders to satisfy five user defined requirements: a) to provide total patient accountability and medical regulating (tracking and scheduling patients through the evacuation chain) in real time from the first physician encounter; b) to keep evacuations and patient movement to a minimum and maximize return to duty; c) to deliver rapid world-class response to trauma; d) to leverage the expertise of medical specialists located in Germany and the United States in support of forward deployed units in Bosnia and Hungary; and, e) to provide medical leadership with enhanced situational awareness through networked information management systems and VTC at all levels of medical support.

Deployed Technologies

Primetime III has provided Operation Joint Endeavor medical units with the most robust set of telemedicine technologies deployed in a contemporary operation to date. Primetime III was planned and executed using rapid prototyping and "rapid systems integration" strategies; the Primetime III Task Force director employed a "brokering" strategy, bringing a variety of systems prototypes and prototypers together to produce a loosely integrated, nearly complete systems solution to the telemedicine and medical informatics objectives. This horizontally and vertically matrixed approach minimized organizational mass while optimizing function by leveraging the capabilities of DoD, Army, Navy, and Air Force units, the Defense Information Systems Agency (DISA), DARPA, and industry-academic partners including GTE, Northrop Grumman, Teleos, N.E.T., SAIC, United Medical Network, United Medical Network, Johnson & Johnson (Ethicon Division), CLI, Picturetel, Vector Research, and Georgetown University.

Units were fielded with Picturetel and CLI, Inc., high-resolution, 384-kilobyte-per-second (kbs), 30 frame-per-second (fps) systems capable of high bandwidth, real time interactive VTC. American Medical Development provided integrated digital diagnostic scopes sets to augment the interactive VTC.

Georgetown University designed, deployed, and installed a radiology local area network (LAN) system capable of providing filmless medical imaging and transmission of computed tomography (CT) scanning, computed radiography (CR), and full-motion, color doppler ultrasound.

United Medical Network developed a deployable telesurgical mentoring operating room suite that provides laparoscopic scope, overhead, and room view interactive, bi-directional audio and video transmission to support complicated surgical cases in Bosnia. A similar digital radiology and teleradiology system was employed onboard aircraft carriers offshore. This configuration of deployed hospitals, medical centers in Germany and in the United States, and shipboard hospitals, each configured with an internal radiology LAN interconnected to the other hospitals by a virtual wide area network (WAN), is the first radiology implementation of the seamless continuum of support envisioned by the DoD's TMIP program.

"Primetime III has provided Operation Joint Endeavor medical units with the most robust set of telemedicine technologies deployed in a contemporary operation to date."

The U.S. Air Force MEDSITE team from Brookes Air Force Base in San Antonio, Texas, in conjunction with the Army office for Defense Medical Information Systems at Walter Reed Army Medical Center in Washington, D.C., provided and fielded an enhanced deployable version of the CHCS, the DoD's integrated hospital information system. As deployed, CHCS(D) initiates computerized medical record keeping in the field; facilitates far forward delivery of laboratory, radiological, and prescription support; and provides clinical electronic mail for collaborative care among widely dispersed clinicians. In another entrepreneurial effort, patient administration and medical regulating functionality of the Army's Theater Army Medical Information System, the CHCS(D), and the Defense Medical Regulating Information System (DMRIS) were significantly enhanced by a prototype PC/Internet-based real-time patient tracking system developed by the Army's Patient Accounting Systems and Biostatistical Agency (PASBA). Dubbed PARRTS (Patient Accounting and Real-time Reporting Transmission Systems), this prototype system allows military medical officers and tactical commanders to access computerized patient data and track evacuations. Primetime III also provides enabling technology to access online clinical databases via the military and civilian internet and to deliver teledentistry services.

The Uniformed Services University of Health Sciences Combat Casualty Care Research Center provided all on-site clinical training. The DoD Health Affairs TMIP office, in conjunction with DARPA, is providing the medical informatics integration strategy.

All these systems are supported by a collaborative MATMO, DISA, GTE telecommunications systems integration solution that provides satellite and terrestrial high bandwidth (approximately 1.536 Mb/s (megabits per second)) telecommunications support to forward forces at Taszar, Hungary, and Tuzla, Bosnia, 128 kbs International Maritime Satellite (INMARSAT) communications to dispersed clinics throughout Bosnia, and 384 kbs terrestrial connectivity to U.S. military medical centers in Washington, D.C., Texas, California and Hawaii.

PRIMETIME III CAPABILITIES LIST

FILMLESS, COMPUTED RADIOGRAPHY
COMPUTED TOMOGRAPHY
HIGH-RESOLUTION VIDEOCONSULTATION
DIGITAL DIAGNOSTICS
STILL IMAGING
HOSPITAL & PATIENT INFORMATION SYSTEMS

Satellite
T-1
1.536 Mb/s

Terrestrial
T-1
1.536 Mb/s

384 kbs
30 fps
Interactive
VTC

TCP/IP
Medical Image
Transfer

CLINICAL E-MAIL
TELERADIOLOGY GATEWAYS
FULL-MOTION DOPPLER ULTRASOUND
LAPRASCOPIC & ROOM VIEW TELESURGICAL MENTORING
TELEDENTISTRY
INTERNET ACCESS

MEDICAL SITUATIONAL AWARENESS

Figure 2. Primetime III Telemedicine and Medical Informatics Capabilities List

A combination of satellite and terrestrial telecommunications allows for connectivity with the USS *George Washington* and USS *Enterprise* aircraft carriers offshore in the Adriatic Sea. The carriers were equipped with similar capabilities for filmless radiology, teleradiology transmission, real-time, interactive VTC, and patient information systems (Figure 2).

Concept of Operation

Primetime III is an example of a mission-critical new technology integration project executed under intensive deadline pressure. Less than two months elapsed from the time the operation was ordered to the time the first augmentation was fielded at Landstuhl Regional Medical Center (LRMC).

The operation was originally organized into three telemedicine augmentation phases. A fourth phase was added to focus on the integration of emerging technologies, including the development of a transmittable and transportable electronic patient record. Other potential technology introductions include a prototype three-dimensional portable ultrasound, remote PC-based telepathology, and the LSTAT system.

In Phase One, the task force fielded telemedicine augmentation packages and supporting high-bandwidth communications to the LRMC in Germany, the 67th CSH in Hungary and the 212th Mobile Army Surgical Hospital (MASH) in Bosnia. The LRMC is a fixed facility regional center servicing active duty and family members in Germany; the 67th CSH and 212th MASH are mobile army hospitals deployed in the operational area, consisting of a combination of tents and hardened shelters. In addition, during Phase One, the USS *George Washington* was equipped and positioned off the coast of Bosnia in the Adriatic Sea. High-bandwidth telecommunications and VTC were also provided to military community hospitals and command and control elements in Germany.

In Phase Two, six operating base medical units in Bosnia were fielded and trained. These medical units are much smaller than the hospitals and are designed to support troop concentrations of a few thousand. They have a limited holding capacity for short periods of time, and received lower bandwidth, more easily deployable INMARSAT B (128 kbs) supported capabilities for VTC, still imaging, medical information system access, and at some sites, teleradiology transfer.

Phase Three is intended to provide telemedicine coverage for the remaining operating base medical units. At this writing the exact number and location of these units is being determined by theater medical commanders based on projected operational requirements in the later stages of Operation Joint Endeavor. The intent throughout the operation has been to provide total package fielding, including comprehensive new equipment training, maintenance and sustainment of telemedicine augmentation packages. Task force personnel have made multiple trips to Europe for forward fielding, installation, training, and follow-up.

The completed augmentation is an integrated, worldwide telemedicine-enabled health care delivery system (Figure 3) extending from remote clinic sites in Bosnia to major medical centers in the United States.

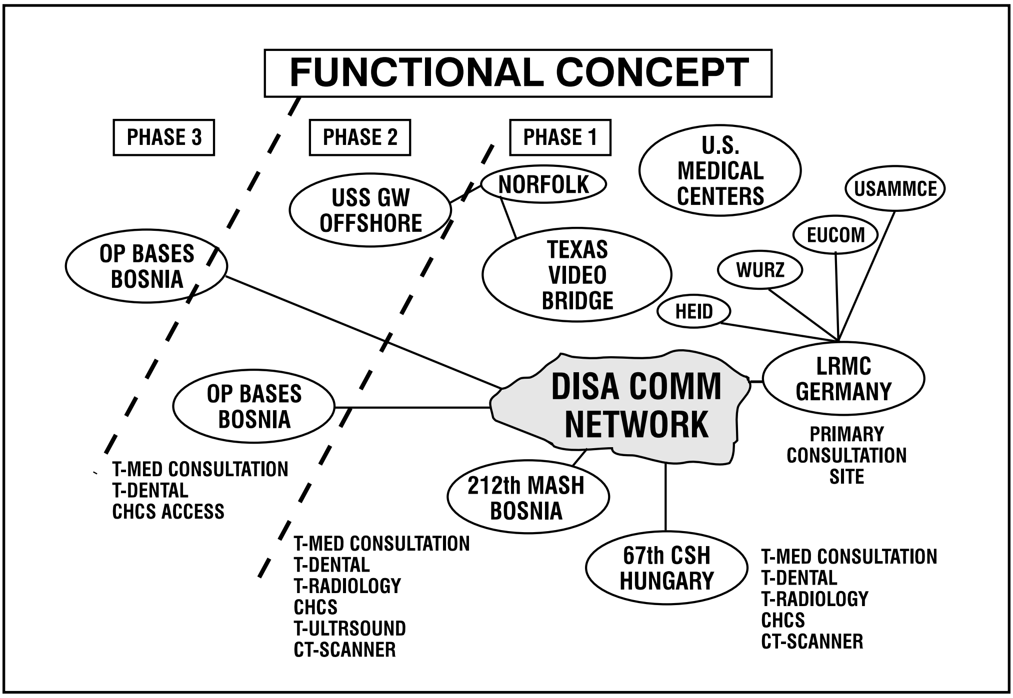

Figure 3. Functional and Operational Concept for Primetime III Telemedicine Support for Operation Joint Endeavor in Bosnia and Hungary

The medical centers designated to provide direct support to forces in Bosnia are organized to be able to provide 24-hour time zone arrayed teleconsultation support (Figure 4). One medical center (Walter Reed Army Medical Center) is located on the east coast of the United States. The second medical center (Wilford Hall Air Force Medical Center) is located in the center of the United States in another time zone. The Navy Medical Center in San Diego is located in California, and Tripler Army Medical Center is located in another time zone in the Pacific Ocean. Each hospital has a slightly different composition of specialist and core competencies. The combination of time zones and specialty populations offers, clinicians in Bosnia with a deep reservoir of teleconsultation support, continuing medical education, and medical information.

System Utilization

Initial results from the first four months of the operation are shown in Tables 1 and 2. Table 1 displays the recorded system use and Table 2 depicts the operational reliability (up-time) of the various technologies and functionalities employed. Radiology was the most widely used telemedicine application. Since the only radiologist present within the theater of operations was located at the CSH, physicians at the MASH had to use teleradiology for radiology procedures that required the presence of a radiologist. More than 800 X-rays were

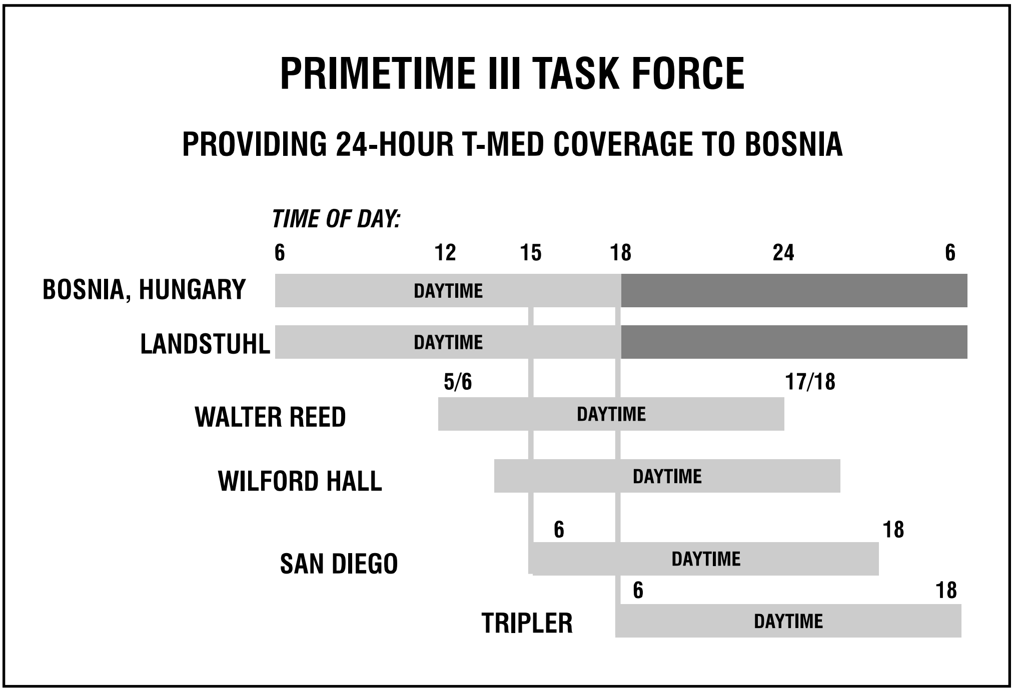

Figure 4. Medical Center Telemedicine Consultation Support for Operation Joint Endeavor, Organized to Provide 24-hour Coverage

transmitted from the MASH in Bosnia to a CSH in Hungary during the first four months of the operation. Similar use was made of the CT and ultrasound applications. Still image and full motion video consultation capabilities were used less. Several factors may account for these results. First, the caseload in Bosnia and Hungary during this period was very light. The troops deployed were in generally good health and there was no significant hostile action. Second, the training and op-

Table 1. System Utilization

APPLICATION	OP BASES TO LRMC	MASH/CSH TO LRMC/CONUS	67th CSH TO LRMC/CONUS	NAVY CARRIERS TO CONUS
Clinical VTC	4	28	39	36
Digital Radiography	N/A	3,969 Transfer 814	2,413	3,700 T-RAD
CT Scanner	N/A	207	37	Not Reported
Ultrasounds	N/A	98	Not Reported	8
Continuing Medical Education (CME)	0	40	3	2

Table 2. System Operational Reliability (% Up-Time)

SYSTEM	OP BASES	MASH/CSH	67th CSH	NAVY CARRIERS
Clinical VTC	No Data to Date	97%	100%	100%
High Resolution Still Image	No Data to Date	100%	N/A	N/A
Computed Radiography	No Data to Date	97%	97%	100%
CT Scanner	N/A	95%	95%	N/A
Ultrasounds	N/A	99%	98%	No Data to Date
Laparoscopic/Telesurgery	N/A	75%	N/A	N/A
Teledentistry	No Data to Date	N/A	100%	N/A
Medical Information Systems	No Data to Date	100%	100%	100%
Continuing Medical Education	No Data to Date	70%	75%	No Data to Date

erational support for the systems was initially inadequate. Third, the systems experienced significant end-to-end downtime due to insufficient technical support, slow delivery of repair parts, and initial inadequate network operational priority. In the case of high-resolution still imagery at the MASH, the capability was inadvertently omitted from Phase 1 implementation all together. (See communications and sustainment discussions below.) These shortcomings were subsequently addressed by the task force director but are strongly reflected in the initial system utilization results. The most significant uses of the full-motion VTC capability were for graduate medical education (GME) and career counseling. The laparoscopic surgery technique was highly accepted by the physicians in theater but due to lack of caseload there were very few surgeries conducted. The teledentistry system was also popular and easy to use but was not implemented until Phase 2, and therefore no initial results were available at this writing.

In the area of medical informatics, the success of the deployable CHCS hospital information system within the deployed hospitals was apparent from the start. It was professionally installed and adequately supported by the Air Force MEDSITE team; training provided was excellent and most of the health care providers had had previous experience with the system at their permanent duty stations, so user satisfaction was high. Since the forward areas order entry and results retrieval application of CHCS was not implemented until Phase 2, no initial results were available at this writing.

Like CHCS, the prototype PARRTS system was highly accepted by users both in the area of operations and in the supporting medical centers and commands. Even the service surgeons general and Assistant Secretary of Defense for Health Affairs in Washington, D.C., logged on to the PARRTS system via the Internet to obtain daily Operation Joint Endeavor medical situation updates. A total of 2,357 patients were registered in the system (i.e., treated at the MASH or the CSH) within the first six months of the overall operation.

Initial Lessons Learned

Space Communications and Network Management

The Space Communications and Network Management Team was responsible for the technical design and integration of the telemedicine network. This team created the detailed communications and forward deployed networking lay-down that provided for a commercially available, standards-based and scaleable infrastructure capable of supporting time-sensitive applications. The network was to have a multiuser, multifunctional architecture that maximizes infrastructure reuse. The network was to require minimal customization with maximized use of COTS equipment for rapid procurement, validation, and deployment. The network was also to have a minimum need for on-site communications staffing and a remote network management capability.

Within the time, cost, and operational constraints of Operation Joint Endeavor, all of these objectives were unobtainable. Rather than build a separate telecommunications network optimized to meet the aforementioned medical requirements, the task force shared bandwidth on the common high-bandwidth telecommunications network provided in theater. This network was not optimized for medical use, and was unavailable at times. Because it was not a dedicated medical network, medical personnel did not always have adequate visibility of the causes nor the final solutions to network telecommunications problems that affected the continuity of telemedicine enabled care.

A "stovepiped" medical telecommunications network, restricted to medical traffic and fully under the control of medical personnel, would probably have provided optimal functionality; medical personnel could have rapidly isolated, identified, and corrected network problems. In practice, this approach is not cost effective, it effectively inhibits information interchange between medical and nonmedical commanders, and is not operationally feasible from warship medical facilities. Shared telecommunications among medical and nonmedical requirements in deployed environments is the most feasible use of scarce bandwidth in the austere operational environments most likely to require telemedicine support. In the future, medical personnel will have to better communicate their requirements, telecommunications providers will have to better understand how medical requirements differ from other forms of communication, and better tools must be made available to medical personnel to monitor the performance of shared telecommunications pipelines. In this way, medical personnel will be able to anticipate problems and bottlenecks and proactively take corrective action to ensure that long-range com-

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munications are available based on medical need.

A corollary to this finding is that medical organizations need to restructure to provide the expertise necessary to perform, or assist in the function of network conceptualization, development, and management in future operations. Even if military medical personnel had obtained the full remote monitoring, diagnostic, and network management capability that was sought, it is not altogether clear where DoD medical personnel would have secured sufficient skilled personnel to perform remote network management and troubleshooting 24 hours a day, 7 days a week. The DISA has traditionally provided long-haul strategic communications, but if the agency is to effectively support functional technologies such as telemedicine, providing a reliable back-bone communications infrastructure is not enough. More flexible and responsive network management and prioritization policies and procedures as well as end-to-end systems integration services and support are also essential. As health care delivery moves further into the integration of telecommunications and medicine, it is important that we think creatively about changed roles and responsibilities. One option is to leverage existing communications capabilities, such as call centers, in major medical centers.

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Clinical Operations and Training

From the outset, the Clinical Operations and Training were viewed as a key success factor of this rapid prototyping implementation. The Clinical Operations and Training Team was responsible for coordinating with and supporting the medical commanders in developing a comprehensive telemedicine program.

Telemedicine changes the familiar patterns of health care delivery and referral. These new patterns must be anticipated, trained for, and used in order to achieve desired clinical outcomes. The telemedicine networks are established foremost to support the physicians that must deliver health care in an austere and demanding environment. The clinical team is the physician advocate within the Primetime III task force.

The clinical team consulted widely in theater and at supporting medical centers to develop guidance on a wide range of clinical issues. Among these were the clinical utilization protocols for particular telemedicine technologies, medical center teleconsultation and scheduling policy, appropriate documentation for telemedicine enabled procedures, implementation of a technology acceptance and utilization strategy, and identifying continuing medical education (CME) use of the network.

The clinical team developed training plans and a training schedule that aligned with the projected phased site implementation time line. The training addressed not only the operation of the equipment, but also the full spectrum of protocol taxonomies and telemedicine applications for the provision of health care.

In practice, we found that the effectiveness of training varied between units. In some cases, the task force had to redeploy trainers to provide additional sustainment training. This area—training development and execution—requires additional focus. Human-technology interface, work pattern changes, and medical efficacy concerns that many clinicians believe telemedicine raises are specific areas that require additional research and special attention. Overcoming these human issues are the most difficult element of most government related organizational-technological improvement programs (Candle, 1994).

A second difficult area is coordinating interactions between U.S. medical centers and the forward-deployed field hospitals. There are many opportunities for interaction between forward facilities and medical centers. In practice, the level of interaction between the U.S. medical centers and the units in theater varied widely. Some medical centers experienced fairly frequent contact, others rare contact. One of the impediments to greater contact may have been that we lacked concrete information and procedures for interaction between the two levels of care. An infrastructure of procedures and detailed resources available at each medical center and field treatment facility would probably facilitate more effective and frequent consultation. This too is an area that requires additional research.

At a minimum, training of clinicians on telemedicine must start in the peacetime health care delivery system and be sustained in routine medical practice, if it is to be optimized in deployed settings. Standardized training materials, not only in the operation of telemedicine equipment, but also in the process changes that telemedicine creates, must be developed. These new procedures must be used, and refined in routine medical practice and institutional training programs.

Though the task force devoted significant resources to the identification and resolution of technical problems, we may have underestimated the difficulty of managing human and organizational change in a compressed time frame under stressful conditions. These process changes are essential if these new technologies are to be used to their full advantage in enhancing access to and quality of care. Maneuvering full circle to the emerging concept of the Secretary of Defense for DoD Research, Development and Acquisition, we must devote equal resources to both "product" and "process" change in an integrated approach.

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Operations and Sustainment

Like training, operational sustainment and logistical support are as key to the success of rapid prototyping efforts as they are to traditional development, acquisition, and fielding processes, especially if prototyping is to occur in real-world situations. The major weakness of the Primetime III prototyping effort is the lack of integrated logistical support. Under traditional product acquisition methodologies, a complete operational and logistical sustainment package is developed and tested as part of the acquisition process. In its early stages, a rapid prototyping development model is not intended to be a complete solution; therefore operational sustainment is not likely to have been fully planned and tested prior to prototype testing by the user. But if this user testing is intended to be carried out in a real-world environment, the prototyper must either provide "hand-holding" operational and logistical support or develop a sustainment package.

In the case of Primetime III, direct logistical support and indirect operational support was intended by the task force director. This proved to be insufficient, if not unworkable. Providing technical problem analysis, maintenance troubleshooting, repair parts, and component replacement support from MATMO headquarters in Frederick, Maryland, even through a network of government and contractor support personnel in-theater, did not work effectively. Repair parts and component replacements could not be procured within the United States and shipped into the theater of operations fast enough to be responsive to the medical task force needs. Likewise, user–operator confidence and proficiency languished each time the clinical operations and training team withdrew; when user technical proficiency languished so did use of the system for consultations. To remedy these problems, the Primetime III task force inserted permanent technical and operational support personnel on the ground to help personnel use the system, conduct troubleshooting and system repairs, and coordinate assistance from MATMO and the Primetime III contractors.

Clearly, rapid prototyping operations that are conducted in real-world environments, especially in remote ones, must be directly supported by the prototyper on-site or must be modified to provide adequate user operational training and an integrated logistical sustainment framework prior to deployment. MATMO and the U.S. Army Medical Command are currently developing plans for a provisional Deployable Telemedicine Units at Fort Bragg, North Carolina, and Fort Hood, Texas, as an organic component of the Army's operational Forces Command 44th Medical Brigade. The intention is to improve medical readiness and the effectiveness of future telemedicine deployments by fielding prototype telemedicine systems directly to operational forces for operational testing, training, and development of logistic support plans and procedures prior to deployment.

EVALUATION

No problem solution methodology is effective without an effective means of evaluating the results. The most widely accepted scientific approach to evaluation is a prospective approach with control groups. In the case of Primetime III the evaluation effort focused on operational, clinical, and technical aspects of the operation. The effort was intended to be prospective from the beginning; significant monetary, personnel, and materiel resources were devoted toward evaluation. This included hiring two independent contractor organizations to support the military's own evaluation effort: one to evaluate the technical feasibility and operational performance of the Primetime III systems; the other (hired by the DoD Telemedicine Evaluation Working Group [TWEG]) to support the Army Medical Department (AMEDD) Test Board in its own efforts to evaluate the operational and clinical aspects of the operation. The

AMEDD Test Board actually sent a team of military data collectors into the theater to observe the clinical use and operational performance of the Primetime III telemedicine systems, as well as the Primetime III task force team itself. A Lotus Notes database designed to capture key evaluation data elements was developed and fielded as part of the evaluation effort. The evaluation contractors relied heavily on data collected by the AMEDD Test Board team via the Lotus Notes system and on the contents of clinical and administrative e-mail to prepare their evaluation reports.

The evaluation team is responsible for ensuring that the in-theater data collection process, which will form the basis for evaluation analyses, is seamlessly integrated into the health care delivery process, and does not impede the health service mission. Questions that the combined clinical and technical evaluation will address include the following: Does telemedicine reduce the anticipated level of patient evacuations? Does it reduce turnaround time of radiological and laboratory reports?

Does telemedicine reduce the travel distance and time required to receive specialty care and consultation? Does it reduce patient admissions and increase the percentage of return to duty? Does it reduce cost of radiological film processing? Does filmless radiology reduce logistical requirements? Does telemedicine provide better patient imaging than current film-based processes? Does telemedicine reduce the loss of medical images (films)? Does it decrease the retake rate of radiological images, and does it reduce supply and personnel costs versus the development of film? Does telemedicine increase the efficiency and effectiveness of medical staff? Under what conditions is telemedicine most useful?

A related, but separate line of inquiry are questions of technical adequacy. For example, does the technology adequately support the clinical needs and processes? Are the components of the telemedicine augmentation sets interoperable? What factors affect the input of medical data? What factors affect the throughput of medical data? What factors affect data compression and pretransmission image modification? What factors affect image resolution and video display effectiveness? How does the technology effect the efficiency and effectiveness of the delivery of health care?

"The evaluation team is responsible for ensuring that the in-theater data collection process, which will form the basis for evaluation analyses, is seamlessly integrated into the health care delivery process, and does not impede the health service mission."

While no definitive evaluation reports have yet been submitted, early observations by the evaluation teams were most useful to the Primetime III task force director in initiating technical, operational, and clinical improvements in the system and to the support structure.

Some initial system utilization and performance data are shown in Tables 1 and 2. It is clear from this data that first, there is insufficient data for a robust evaluation of the clinical effectiveness of the telemedicine system—primarily because of the lack of patient workload in theater.

The troops deployed were basically healthy and there was virtually no hostile activity during the period of data collection. Therefore any evaluation of the usefulness of the telemedicine system for theater combat casualty care based on the data collected will be biased due to lack of caseload.

Second, while the system technical and operational reliability is certainly relevant to the evaluation of the prototyping effort, it automatically introduces biases into any evaluation assessment of the usefulness of the telemedicine system as a tool for health care. If the system functions poorly, clinicians will cease to use it and their active assessment of its utility as a health care tool will be negative.

Care must be taken in choosing operational environments for rapid prototyping testbeds to ensure that sufficient caseloads exist to adequately test the prototype system *and* to ensure that the prototype technology is sufficiently reliable so that the results of evaluation of the business process (in this case, telemedicine) are not biased by poor technical performance.

"These findings will inevitably lead to improved use of information technology and advanced disgnostics in health care as well as improved systems that better meet the needs of military and ultimately, civilian users of telemedicine and medical informatics capabilities."

The lessons learned above are preliminary assessments, and could change as the operation and evaluation continues, and more detailed findings become available. These findings will inevitably lead to improved use of information technology and advanced diagnostics in health care as well as improved systems that better meet the needs of military and ultimately, civilian users of telemedicine and medical informatics capabilities.

SUMMARY AND CONCLUSION

The Department of Defense is exploiting rapid prototyping and "rapid integration" of commercial off-the-shelf technologies to acquire and field test telemedicine applications in support of real-world military operations. Primetime III was organized by the Department of Defense Telemedicine Testbed at Fort Detrick, Maryland, to conduct a proof of principle demonstration and field tests of several telemedicine and medical informatics technologies in Bosnia and Hungary. Among the technologies and functional capabilities selected were high-resolution still imaging, full-motion video teleconferencing, digital radiography, computed tomography, real-time ultra sound, teledentistry, laparoscopic tele-surgery, teledentistry, electronic mail, Internet and World Wide Web access, and an integrated hospital information system. The most widely used application was digital radiography: a radiologist at only one of two deployed hospitals read and interpreted more than 800 X-rays transmitted via teleradiology in the first four months of the operation. Initially inadequate training, technical support and operational reliability as well as lack of caseload contributed to low system use for still imaging and full-motion video teleconsultation systems. Medical informatics systems including a deployable version of the DoD CHCS and a prototype PARRTS were successfully implemented and favorably received by users.

An important element of the Primetime III augmentation is the evaluation of clinical and technical effectiveness of the deployed systems. Prior to deployment, a comprehensive evaluation plan that establishes performance metrics and a strategy to measure clinical and technical effectiveness and efficiency was designed.

Among the initial lessons learned were that the DoD Telemedicine Testbed needs to implement more structure into its rapid prototyping and rapid integration process if it continues to exploit real-world military deployments as telemedicine testbeds. The DoD needs more flexible and more effective policies and procedures for shared use of telecommunications bandwidth among medical and nonmedical users if telemedicine is to be effectively integrated into the military health service system without stovepiped, dedicated communications. The importance of clinical and technical training and establishing uniform telemedicine consultation protocols and procedures at both the sending and receiving ends cannot be overstated. Telemedicine changes both the way medicine is practiced and the way health care is provided logistically; this cannot be achieved without well-defined business practices and adequate training. Likewise, adequate technical support and logistical sustainment must be provided if physicians are to develop enough confidence in telemedicine systems to rely on them. Systems that don't work won't be used. Even in a rapid prototyping, proof of principle operation, adequate planning and procedures for providing user training and sustainment support must be implemented if patient care is involved.

The observations presented in this paper are only preliminary ones. It is too early to comprehensively answer the evaluation questions constructed for the Primetime III effort. Nonetheless, it is clear that the deployment in Bosnia will provide the U.S. military health service system with valuable information about the appropriate use of emerging telemedicine and medical informatics technologies in support of military operations. We are learning that rapid prototyping and matrixed organizational approaches that leverage distributed expertise while minimizing organizational mass can be effective at responding to rapidly changing requirements. Conversely, we are also learning how important it is to really understand user requirements and organizational change, if technology use is meet expectations. Most important, we have learned that it is easy to underestimate the work required to manage human factors that ultimately determine whether tele-medicine will be used to its full advantage to improve access to care, decrease the cost of delivery, and improve quality.

"Telemedicine changes both the way medicine is practiced and the way health care is provided logistically; this cannot be achieved without well-defined business practices and adequate training."

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TECHNICAL APPENDIX

Task Force Primetime (TFPT) III capabilities are implemented in an iterative-phased process. When complete, the augmentation will provide an integrated telemedicine network for Task Force Eagle medical units. The network will include the LRMC, the 67th CSH, the 212th MASH, 2 Brigade Operating Base (BOB) medical units (possibly 27), and access to the USS *George Washington* in the Adriatic Sea, off the coast of Bosnia.

The high data rate communications network will be capable of supporting:

a. High-resolution, diagnostic quality, remote video telemedical consultations.

b. Remote specialty surgery mentoring to MASH.

c. Digital diagnostic scopes.

d. High-resolution, color, still image capture.

e. CHCS access.

f. TAMMIS.

g. Clinical E-Mail.

h. Teleradiology.

i. CT scanning.

j. Full-motion, real-time ultrasound.

k. CR filmless radiology.

l. Teledentistry.

m. Telepsychiatry.

n. Medical situational awareness.

o. Preventive medicine consultations.

p. Infectious disease consultations.

q. Internet access.

At the discretion of the Task Force Eagle Commander, the integrated network (Figure 1.) also allows for access to fixed facility, tri-service medical centers in the United States. The network will also be designed to be capable of expansion and integration with the support of additional Air Force, Navy, and Allied forces medical units and leading edge technology insertions by DARPA, as necessary.

VOICE

Each location is equipped with a Micom Marathon switch and two telephones. Voice connectivity between the TFPT III locations is provided by three 256-kilobits-per-second (kbps) frame relay permanent virtual circuits provisioned through the IDNX nodes. Connectivity to the Defense Switched Network (DSN) is provided by extending six subscriber lines from the DSN switch at Lanstuhl to Foreign Exchange Office (FXO) modules in the Micom switch at the LRMC. The six DSN lines shall be configured for Dual-Tone Multifrequent (DTMF) signaling.

VIDEO

Minimum of two VTC units are provided at each field location. VTC Unit One serves the clinic, and VTC Unit Two serves the Operating Room (OR). The VTC units installationed in the OR have been equipped with special camera units and wireless microphones. The VTC units at the Taszar CSH and Tuzla MASH are connected to ports A1 on two separate Teleos Model 20/A1T/2P Access switches, which, in turn, are connected to the network through one Primary Rate Interface (PRI) network interface each to the IDNX. The third Teleos Access switch installed at Taszar and Tuzla are spares. At the LRMC, two Teleos Model MCU-1T/16B/2P/4M Video Hubs are installed which, in addition to VTC interfaces, also have four Multipoint Control Unit (MCU) ports, which will be used to set up multipoint conferences.

VTC equipment from two manufacturers is used. The LRMC and Tuzla MASH will have CLI Radiance equipment, while the Taszar CSH will have PicTel units . It should be noted that while the CLI Radiance units are capable of setting up full-bandwidth conferences at 1.472 Mb/s (using 23 Basic Rate Interface (BRI) channels), the PicTel units at Taszar CSH are limited to a maximum of 768 kbps (12 BRI channels) conferences.

VTC connectivity between TFPT III locations is provided through the backbone transmission system that has the capacity to accommodate one point-to-point conference at 1.472 Mb/s or two point-to-point conferences at 768 kbps between any two field locations.

Off-net access to the German commercial network will be provided at Landstuhl by leasing 12 BRI Euro-ISDN lines from the Deutsche Bundespost (DBP). This access will be used to arrange conferences between TFPT III locations and Heidelberg, Wuerzburg or U.S.European Command (USEUCOM).

Off-net connectivity to the San Antonio MEDNET gateway will be established through a 384 kbps line (to be increased to 1.536 Mbps at a future date).

Multipoint conferences can be arranged for up to four locations using one of the two Teleos MCU-1T/16B/2P/4M units installed at the LRMC or for up to six locations by connecting the two MCUs together through one pair of the MCU ports, leaving three ports on each unit for VTC locations.

DATA COMMUNICATIONS

A local area network (LAN) serving teleradiology provided access to a high-speed (1.536 Mb/s) frame relay network through a Cisco router located in the communications equipment area and a LAN hub located in the teleradiology equipment room. Frame relay connectivity is provided by private virtual circuits (PVCs) with Data Link Connection Identifiers (DLCIs).

A LAN serving support systems such as TAMMIS, DMRIS, and e-mail is connected to a LAN hub located in the clinic and provided a 64 kbps access circuit to the N-level Internet protocol (IP) routing Network (NIPRNET) through the Cisco router and the Integrated Digital Network

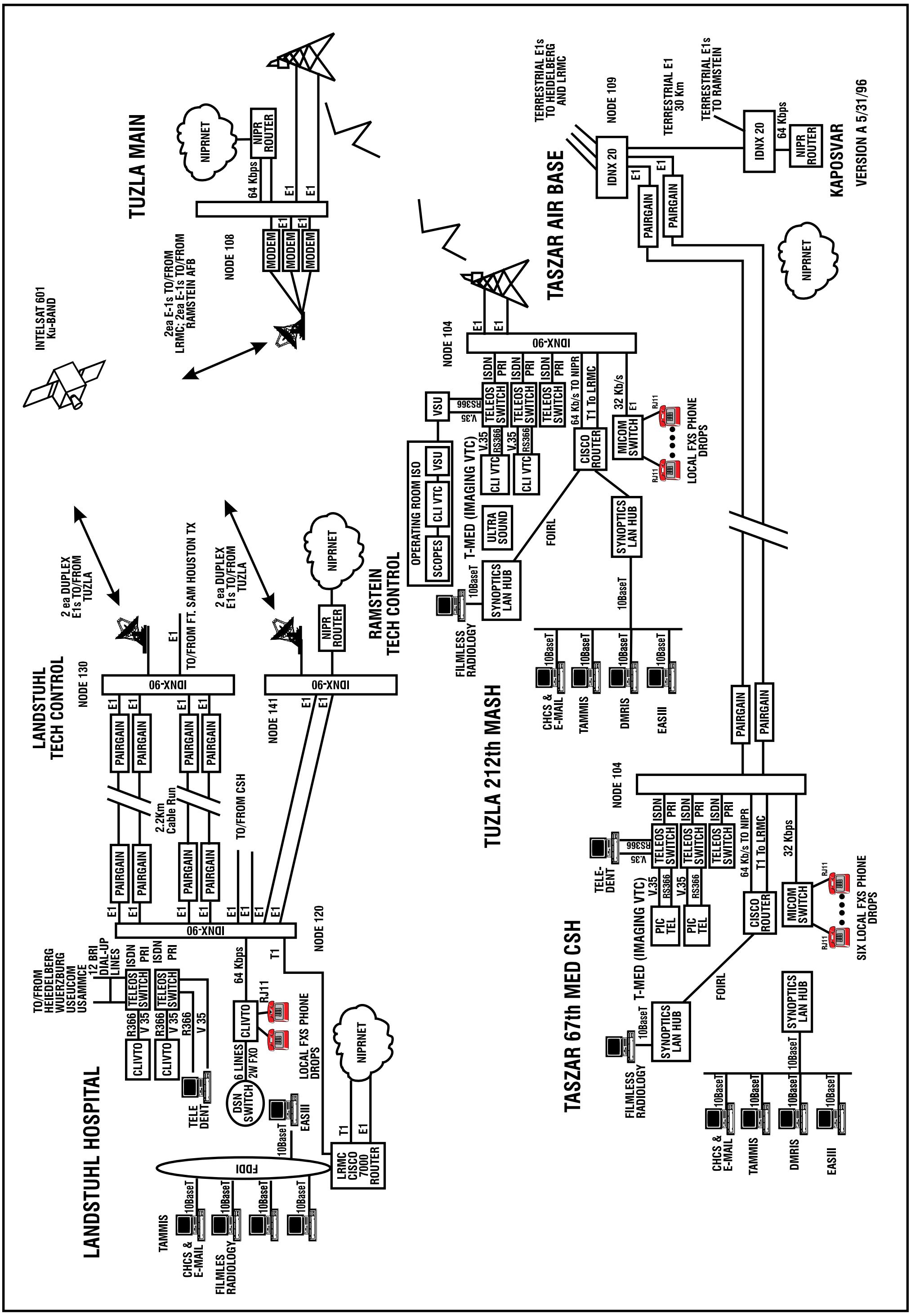

Figure 5. Primetime III Network Configuration.

Exchange (IDNX). Figure 5 shows the network configuration.

Teleradiology

LRMC

Landstuhl Regional Medical Center was established as a referral hub for secondary reading and as a site for clinical consultation with telemedicine. Equipment includes 2K diagnostic workstations and a 1K high luminescence image evaluation workstation, a dry laser printer with a print server, and digital imaging communication for medicine (DICOM) image gateway.

67th CSH, Hungary

The 67th CSH was established as a primary referral center for images obtained in the theater and diagnostic center for Hungary. Equipment includes 2K diagnostic workstations and 1K high luminescence image evaluation workstation, and a dry laser printer with a print server. Images are acquired on phosphor CR plates and processed in a laser processor. The equipment is connected to a Synoptics hub and to the WAN through a Cisco router.

212th MASH, Bosnia

The 212th MASH was established as a diagnostic center for Bosnia. Equipment includes 2K diagnostic workstations and 1K high luminescence image evaluation workstation, and a dry laser printer with a print server. Images are acquired on phosphor CR plates and processed in a laser processor.

The equipment is connected to a Synoptics hub and to the WAN through a Cisco router. The ultrasound machine is connected to the NTSC port of the telemedicine codec to provide real-time ultrasound.

Image Archive and Report Generation

All images are archived at the MASH. Images are initially stored on the 9Gig RAID array, then archived FIFO on optical disc.

Radiographic reports are entered manually by the radiologist at the CSH. A series of macros have been written to speed the process of report generation and approval. Reports are telnetted to the MASH from the CSH.

Technical Problems in Teleradiology

Occurrences in the teleradiology system are designated major or minor events. Major events are those that may or do have a direct impact on patient care. Minor events are abnormal occurrences with no potential for direct impact on patient care.

One major event had a direct impact on patient care: 16 images were lost from a CR study and the exam was repeated on conventional film. When the initial 16 images were selected to merge into one study there was a lack of disk space in the swap partition and the images were lost. This has been prevented by instituting procedural changes until a larger disk drive can be moved to the MASH.

A second major problem has been in the integrity of the communications link from the MASH to the CSH. This has been inoperable for as long as 72 hours. Since some of the voice lines and all Internet lines are carried over this communications link, it is impossible to provide support during these inoperative periods.

Another major event was rain damage of the CR Identification Data Terminal when the tent housing this piece collapsed during a storm. The equipment has been repositioned into an isoshelter to prevent a recurrence.

There have been 11 reported minor events. These usually involve printing or delays in image transmission. They have been resolved without affecting patient care.